AGRONOMY AND THE ENVIRONMENT

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Summary.

Some of Australia's current crop and pasture production systems are now recognised as being unsustainable by scientists, government and rural industries. Deterioration in the resource base is considered to be the primary problem. Solutions to date have concentrated on remediation of on-site soil conditions, with investment in improvements to soil structure and fertility, amelioration of acidity, compaction, waterlogging and salinity, and alternatives to pesticide application. The much larger effects of actual, and potential, off-site impacts from current farming practices have received far less attention from production scientists till recently. Environmental concerns have been precipitated by such issues as secondary salinity and rising water tables, and by the credibility gap between our *clean green* image and the reality of trade violations by pesticides and other contaminants. These off-site impacts may well prove to have larger costs to the total economy than the internal costs from resource degradation within the rural sector.

The solutions to such impacts require radical rethinking of many of our farming practices and landuse options of rural production systems in parts of Australia's agricultural regions. Effective technologies for managing these inputs, integrating perennial and annual plant species, utilisation of native and novel plant products, management of farmed and unfarmed fragmented landscapes, all require imaginative agronomic research.

INTRODUCTION

"If we had discovered England, would we have grazed It with kangaroos?" Campbell (1)

Andrew Campbell, the first national Landcare Coordinator opens his recent book on the Landcare movement with that question to focus the reader's attention on the fact that for the past two hundred years European Australians have been wrestling to use Australian environments with forms of agriculture that complied with their own notions of what could and should be produced; rather than adapting local resources, or those that were already adapted to semi-arid, low fertility environments. With long-continued investment in rural research, Australians have made successful modifications to germ plasm stocks and technologies imported from other environments, to develop what are essentially Eurocentric production systems, typified by very extensive use of land and low input-output volumes per unit area.

Because of the abundance of cheap land and production systems geared to overcoming problems of distance, adjustments to declining terms of trade have mainly come from expanding both the total area of production and the area per farmer. Only in highly productive, well watered regions close to metropolitan regions has the intensification of production been comparable with trends in the horticultural and dairying industries in other parts of the world. And only in the past five to ten years have there been tentative moves to acknowledge that systems of production suited to the very erratic nature of both the climates and markets Australian farmers face may in future be markedly different from the past.

Most of this change in attitude has been precipitated by increasing acceptance that the current systems of agricultural production are not sustainable (2), and in some of the most degraded lands L, these systems are, put bluntly, using land for the wrong purpose (3,4). At the same time there has been better recognition that there is no more cheap land to develop in the southern half of the continent. In northern Australia the recognition that we may still be in time to save large areas of sensitive ecosystems has led to the first real restrictions to further development with the halting of further renewal of pastoral leases on Cape York and the end to legal clearing in New South Wales (1995). These initiatives of State legislation represent a change in values and acceptance that agricultural development is no longer the engine that drives economic growth, but rather that the agricultural sector is now seen as one of several important sectors. While the sector still accounts for a quarter of export value and between 3% and 4% of total gross value of production (5), these figures represent a proportional reduction of fifty percent in a decade, and cannot be dismissed as simply the result of a run of bad seasons, but should be interpreted as the maturation of other sectors in the economy such as tourism and mineral processing.

While there are promising signs that a combination of deregulation and dismantling of protection has stimulated diversification of agricultural products in the past decade, the fact remains that meat, wool and wheat still dominate the gross value of commodities, together making 42% of the value in 1993-4 (5). The majority of so-called new commodities, particularly in crops, have been species that are already grown elsewhere in the world. Australian production is now catching up with other producers of canola, faba beans, chick peas, mangoes, coffee, and even macadamia nuts, an Australian species, domesticated elsewhere. There is the beginnings of an industry in native floral and faunal products, and some novel products such as wildflowers, oriental vegetables and tropical fruits each reach over $30 million per year in export value. However the total value of native flora and fauna still account for less than 1% of rural production, and the Rural Industries Research and Development Corporation budget is less than 8% of the Commonwealth's $126 million contributed to the rural research corporations (6).

THE STATE OF THE AGRICULTURAL RESOURCE BASE

In publication after publication, study after study the key issues of land degradation to Australian rural lands have been extensively catalogued (7,2,8). The list is long, and much of the detailed documentation concerns the degraded state of arable lands, or about 4% of the total land area, perhaps because the very substantial degradation in the rangelands has been difficult to quantify (9). Young and Walker (10) have suggested that the economic loss resulting from small amounts of erosion from high-value, horticultural areas greatly exceeds that coming from erosion of much larger area of pastoral and arable lands in New South Wales. Some types of land degradation, such as fertility decline and surface soil structural deterioration may have been over-emphasised in past studies, from both an economic and a technical perspective. Both can be reversed, and in many cases, cultural practices can improve soil fertility and structure compared with the natural state. Of much greater concern are the irreversible changes that occur through such slow, deep profile changes such as acidification, salinity and pollutant contamination. Many of these are attributable to current farming practices.

In a recent paper (11) we drew the distinction between those issues that are well recognised and those which may be regarded as *sleepers* because their causes and consequences are still being discovered and technical solutions are still sought (Table 1). Another sobering aspect of these statistics is that several of the problems occur together across large parts of the agricultural heartlands of the country (Fig. 1). It is for this reason, if for no other, that agronomists must take this situation seriously and consider the consequences of the large-scale impacts of current farming systems across whole landscapes, not just within small experimental plots, or individual farms.

RETHINKING THE RAINFED PRODUCTION UNIT

I have described the traditional response to declining terms of trade as being those of expansion of the production unit and improvements in on-farm productivity. These have taken place across the whole farm unit in most cases. Much less attention, even in property planning exercises, is given to *re-arranging* the production unit according to land capability classes. Although farming by soil type and using the best land for continuous cropping are both trends in some regions, they remain the preserve of a minority.

Nested scales off-farm production

One alternative is for the whole farm enterprise to be reassessed by retiring some land areas from current production systems completely and concentrating efforts on the remaining portions,- with some, quite small, areas being intensively managed at much higher profit levels. The overall profit, time management, environmental impact and sustainability might well be greater by retiring say up to 30% of the farm (or the district) from current production systems, concentrating efforts on the remaining 70%, using the 30%

savings in time and inputs into off-farm income generation. Such a farm might contain small areas producing high-value small tonnage products with gross margins up to 10 times the value of the broad areas of production, which in turn yield positive incomes in all years: the remaining 'retired' land yields no direct income, but incur few costs.

Table l. Australian land resources: what are the threats? (11)

Recognised problems	Capacity to halt	capacity to reverse	Area affected
Erosion	Yes	Some	10 million ha
Fertility decline	Yes	Yes	> 30 million ha
Salinity i. Dryland	Some	No	2-5 million ha*
ii. Groundwater	Perhaps?	No	0.5 million ha
Rangeland loss of condition	Yes	Some	up to one third (2 million km^2)
Sleepers			
Acidification: i Topsoil	Yes	Yes	~30 million ha
ii.Subsoil	No ?	No	over 30 million ha
Or~anic contaminants	Perhaps	No	20 million ha?
Heavy metal contaminants	Sometimes	Sometimes	Arsenic 10,000 sites Cadmium 40 million ha
Sodic soil deterioration			
i. Topsoil	Yes	Yes	2.5 million km^2
ii. Subsoil	No	No	2? million km^2

* Official statistics from Australian Bureau of Statistics surveys regularly underestimate the area of dryland sa1inity compared with government hydrological estimates by a factor of two.

Degradation Risks for Agricultural Lands

Risk of Degradation by:

Water Erosion, Induced Acidity, Salinity, Woody Shrub Encroachment, Wind Erosion, Water Repellence or Soil Structure Decline

At Risk from:

More than Three Forms of Degradation

Fewer than Three Forms of Degradation

Other Areas:

Unmapped or Low Risk

Non-agricultural lands

Figure 1. Distribution of recorded land degradation problems in Australia, showing those areas with three or more [black], one to three [grey] or one [pale grey] type. (11)

Let us develop this idea for a farm in the 350-450 mm rainfall belt of the mallee lands. It has areas of higher and lower fertility soils which are reflected in a range in the cereal yields of over 100% every year, and in which the sheep enterprises are often only marginally profitable;- when they are factored into contributing to the crop profits. A property plan is developed which identifies the low-return areas. These are then fenced out, integrating them wherever possible with remnant vegetation, waterways and non-farmed areas such as wetlands and rock outcrops. On 65% of remaining land area the farmer invests the same time and input costs (or may use the saved time to run an off-farm enterprise, or contract his labour out) to grow either the same, or higher value products. This more intensive, or higher-value production system may have a higher risk associated with it. This requires a higher time and financial investment, saved from spreading the labour and other variable costs thinly across the whole farm. On the final 5% profits (working capital) flowing from the 65% may be invested in an intensive animal production unit, irrigated floriculture, a processing plant (oil extraction, seed cleaning).

The benefits, even with conventional crops will be: a lower proportion of the total cropped area sown at sub-optimal times a higher proportion of crop managed and harvested at optimal dates

a higher total-input level per hectare of productive land, so that there is less risk of sub-optimal levels of nutrition, weed management, grazing control etc. this will lead to a slow but steady improvement in soil condition, since the majority of *remedial* treatments for degraded arable and improved pasture lands require *higher inputs,* of management (including monitoring) than they are currently receiving. This has been the widespread experience of producers who have been involved in the crop checking programs such as TopCrop, Meycheck, Canola check and Rice check (14).

How do we manage "high input" production sustainably, using less land?

In another papers I have noted how widespread the misconception is that high input systems are necessarily more environmentally damaging than low input systems (15). The critical factor is not the level of inputs but the efficiency of their conversion. High *efficiency* systems should be the objective in every environment, whatever the input level. Some environments will always be intrinsically more productive than others, but increases in productivity are everywhere possible, with the incremental and cumulative reduction in environmental constraints, such as irrigation, manipulation of planting dates and phasic development to optimise the light and temperature regimes, use of soil amendments and fertilisers, integrated pest and weed management.

For this reason, environmentalists advocating drastic reductions in the use of pesticides and fertilisers are missing the mark with developing countries with low levels of input such as Australia. Low levels of fertility, and poor weed and pest control serve only to increase yield variability, as well as decreasing yields *per se.* Most Australian agronomists, if not our resource scientists and politicians, are only too aware of the relationship between the poor performance of our wheat yields and grain protein levels and the exceptionally low levels of fertilizer used, compared with all our trading competitors and other major grain producers (Table 2).

Table 2. Australian fertiliser use compared with other major wheat producers (FAO/IFDC/IFA 1992**).

Country	N+P+K kg/ha*	N+P+K kg/ha	Wheatyield gain
	1972	1992	1952-90 $kg^{-1}ha^{-1}y^{-1}$
Argentina	3	5	19
Australia	29	22	8
Canada	38	47	18
China	52	157(262*)	not available
India	17	52	43
Pakistan	25	107	34
Turkey	27	35(635*)	38
U K	313	359	113
USA	105	95	36

* FAO units are expressed as $N+P_2O_5+K_2O$

**Figures from the FAO vol.38 yearbook (1988) that differ from the FAO/IFDC/IFA (1992); the latter used a wider set of sources including agronomist and fertilizer company records.

Low levels of inputs of herbicides, pesticides and fertilizers do not stop environmental problems occurring in Australia, and in some cases the low levels of inputs have contributed to the problem. With accelerated soil acidification low use of lime across much of the improved pasture and arable zone in medium to high rainfall has led to an excess of anions leaching down through subsoils. In some cases this results in acidification rates ten times the natural rate (16). Lime is a relatively cheap product and was traditionally used in western Europe, but early Australian misconceptions about its apparent cost, and the lack of response to lime led to poor advice to farmers and an ineradicable notion that lime was too expensive and did not pay. The fact that lime may save fertiliser dollars by making existing nutrient stores more available was not a point promoted by extension advisers.

What are the consequences of lack of liming? These are diverse, and range from poor utilisation of research funds into searching for acid-tolerant plants that will buy time for the farmer to continue using current production systems, to increasing the cost of water purification significantly to households where surface waters become contaminated with mobilised dissolved organic colloids and phosphates. Table 3 lists the most significant on and off-site consequences of the accelerated soil acidification occurring from the non-use of lime in agricultural districts.

Table 3. On and off-site consequences of soil acidification

On-site impacts	Off-site impacts
• Restriction in the range of crop species with reduction in profit per hectare ?(most tolerant crops are less profitable)	• Reduction in quantity and quality of high value grains (malting barley, high protein wheats), and risk of heavy metal uptake, especially from regions of historical high production (medium to higher rainfall)
• Reduced efficiency of P-fertiliser use, ? low pasture productivity with little N-fixation	• Mobilisation of DOCs and phosphate into surface waters, with increased water charges to ratepayers
• Eventual dissolving of clay minerals ? subsoil acidification that cannot be rectified	• Decreased water-use efficiency from and headwaters of grazed catchments that further accelerate secondary salinity down-slope
• Drop in land value and land abandoned	

An extensive technical, sociological and economic investigation on the reasons for poor adoption of liming in nine regions of known acidification risk in Australia has recently been undertaken under the sponsorship of Land and Water Resources RD Corporation (17). Among the findings for the low use of lime in some districts the report lists lack of appreciation of the real significance of the effects of acidification by advisers as well as producers, and inappropriate or misleading economic analyses evaluating the benefits and costs. This is an issue that affects not only liming, but most other narrowly-based benefit-cost analyses. When these are undertaken (as is now fashionable) they are frequently restricted to the individual product, research project or to one component of a system. Few attempt to cover what is described as the full social cost (including the off-site costs), or even the interactions between enterprise streams within a production unit (farm) or sector (rural), despite well-known models, such as MIDAS, available for the on-farm interactions. The radical agronomist, interested in testing the impact of new plant products and arrangements of the farm production unit, will need to have a radical economist with whom to collaborate.

I am suggesting this change in approach to a wider interpretation and use of resource economics with agronomy because of the complex nature of the predicted future interactions between current farming practices and the environment. Some of these practices may have such widespread impact in future as to force changes in agricultural land use over large land areas. An example with the use of herbicides will illustrate this complexity.

SCENARIO BUILDING

Herbicide use in marginal cropping regions

In semi-arid, rainfed cropping regions the vulnerability of Australia's fragile soils make conservation tillage and trash retention the only sensible management practice that can effectively control wind and water erosion (18). However, such systems depend entirely on herbicides to control weeds that would otherwise cause widespread collapse of cropping systems. Contact herbicides are now coming under criticism for persistence and operator health threat, although glyphosate can still be relied upon for knock-down efficacy. In-crop weeds of cereals must be controlled by such groups as sulfonylureas or other chemical groups that either are less effective or have produced rapid target-species resistance. Recent estimates suggest that sulfonylureas are used with over half the grain crops produced (Powles pers com). They have been an outstandingly safe and useful group herbicides for over a decade, except in high pH soils, where the main process of degradation by acid hydrolysis does not take place. They are not recommended where the soil pH is over 8.6 because of the known problem of persistence in such soils.

In Australia (as in large grain producing areas of the Middle East, the Indo-Gangetic plain, and north west and central China) there are extensive tracts of land where the surface soil is below pH 8.6, but is very sandy, and overlies very high pH subsoils. In these situations evidence is now mounting that sulfonylureas do not break down but are leached into the subsoil (19). Ominously, this is similar to the fate of triazines in low rainfall environments, which do not become hydrolysed or microbially degraded in high pH, low organic matter soils, and are slowly leached into subsoils and eventually into ground-waters. In many reported instances atrazine has been detected in groundwaters only after twenty or thirty years (20). The fate of sulfonylureas applied to soils with high pH subsoil in districts that have sufficient rain to allow leaching to occur (often as pulses during exceptional rain events) is starting to worry the grain industry more and more.

What should responsible agronomists do in this circumstance? Much of the Australian mallee in the 450-280 winter rainfall belt that has been cleared over the past fifty to eighty years for cereal based cropping (21), contains soils that are starting to show sulfonylureas leaching and persistence to depths of over 2 metres (22). These regions are also prone to wind erosion, and have low fertility soils that require substantial nutrient inputs. Attempts to introduce adapted legumes into these regions are being pursued vigorously in an effort to improve the sustainability of the current rotation systems in which medic pasture legumes do not persist well, and which lack suitable grain legume varieties. At the same time there are concerted efforts are being made to improve the adoption rate of stubble-retention and reduced tillage systems because of the high susceptibility of the sandy mallee soils to erosion.

Where sulfonylureas have been applied to sandy surface soils that overlie very high pH subsoils, systems totally dependent upon graminacae could be developed that might avoid damage from herbicide persistence, or legume-based systems, including shrub and tree legumes, could be selected for herbicide tolerance instead. How much should research into current grain-based production systems be investing to continue supporting such systems anyway, rather than exploring the future alternatives for land use options that may be both more environmentally benign and offer higher returns than farming? Many of these more marginal cropping environments have shown little productivity gain in the past two decades and have few off-farm options in terms of local urban centres that can provide service industry employment. In areas where demographic projections and regional development plans indicate substantial structural adjustment in the near future (23) should we be attempting to sustain or improve current farming systems?

Lessons from the Rangelands

My own view is that innovations in plant sciences will be crucial in investigating alternative plant species necessary for more sustainable rural land use, including small areas of floriculture and tree crops that might use local water sources for supplemental irrigation. This is analogous to the switch needed in animal and rangeland research from concentrating totally upon the idea of a future still based solely on cattle and sheep, rather than on a range of products from vertebrates (including kangaroos), eco-tourism and aboriginal land use. Profitable production units clustered around the most agriculturally productive and stable parts of current rural systems many then survive (24). This view, endorsed in the research objectives of the National Rangelands Strategy now acknowledges the unsustainable physical condition of about a third of the rangelands (25) and the nonviable nature of perhaps half of the enterprises, in a zone that comprises 75% of the total rural area of Australia, but provides only 17% of the value of cattle sold, 4% of the sheep and 14 % of the wool value. These three together were valued at $830 million in

1991-2. This pales before the value from tourism in the zone at $3 billion, or that of mining at $8 billion (26).

Predictive Scenarios

There is enormous interest and demand for predictive scenarios that can tell decision makers and land managers which current farming practices are most profitable *and* least damaging, and whether the two are related (10,~27). A cosy assumption has it that systems of farming that conserve soil, organic matter and nutrients must be both financially more profitable and ecologically more benign than those where there is risk or real decline in soil condition. However there have been disquieting suggestions that no generally positive relationship exists between financial profitability and increased diversification or conservation tillage, although the intangible benefits, such as operational efficiency or erosion control may be of sufficient value in themselves, as has been the case with the northern sugar industry, where up to 80% of the cane crop is greentrash harvested (28). Since its dramatic expansion a decade ago further adoption of conservation practices has tended to stall, and some studies indicate farmers opt for the least-risk, well-tested conventional systems during periods marked by high price fluctuations and poor seasons, although they are well aware of land degradation issues and appreciate the need for them (29~0).

What will happen to the 30% of a farm that is retired from conventional agriculture? In the minds of many anxious farmers it would simply regenerate as *bush,* to become a source of vermin and weeds. This need not, however, be the case. Regeneration can be managed by flash grazing, or by direct seeding and encouragement of native species both in dispersed distributions or in regular alley, cluster or block plantings, (31,~,32). Some of the labour costs saved may be put into selected plantings of the commercial timber~ species (33), or into small investments on essential oils medicinal plants, nuts, honey, cut flowers and other products of woody species. This brings me to considering agro-forestry, or the incorporation of trees and other woody perennials into farming systems. To date there have been notoriously poor success rates with many re-vegetation schemes, and a high demand for better information and stocks for specific localities, improvement in establishment and management methods, and demand for shrub species for forage, essential oils, fruits and nuts. What better reason for good agronomy?

AGROFORESTRY

In developing agroforestry systems for Australian environments, we have lagged well behind other semi-arid and sub-humid lands of lower latitudes, have made small scientific links with centres such as International Centre for Research in Agroforestry, and have yet to create a chair in agroforestry at an Australian university. This is puzzling, set beside the substantial investment in agroforesty promotion schemes instituted by government, such as Greening Australia, Save the Bush, and even Landcare. The need to revegetate significant tracts of cleared land to control hydrological imbalance and particularly secondary salinity, is regarded as axiomatic by the Natural Resource Management Strategy of the Murray Darling Basin Commission, and the Land and Water Resources RDC, the Divisions of the Institute for Natural Resources and Environment in CSIRO and the conservation and environment agencies in State governments. The Federal Australian government's announcement of fifteen specifically designated regions for farm plantations in November 1995, as a part of the restructuring of the forest industries, may provide the necessary stimulus for some of the change previously lacking.

Why is it that research organisations and more particularly, agricultural scientists have failed to seize the opportunity offered by such structural changes to invest more in the areas of sustainable environmental management, novel industry products and agroforestry systems? A quick scan of the past three Australian agronomy conferences for example, shows that the majority of papers have been presented in traditional areas of annual pastures (16%), wheat and other winter grains (27%), perennial pastures (19%) and the soil management (such as nutrition, tillage) affecting these (18%): Low on the list with less than 5% of papers are topics on markets, resource economics, climatic risk and agricultural systems, while new products and agroforestry fare even worse (34). In a recent publication produced for the Prime Minister's Science and Engineering Council in 1995, a number of scientists concluded that one reason for this poor investment in novel rural products and resource-related plant science could be laid at the door of the too-successful and powerful influence of the traditional, commodity-based research funding in agriculture, where investment in on-farm productivity of current commodities is well supported but research on resource management of integrated production systems is undervalued (35).

In some of the Rural Research and Development Corporations the investment on the sustainability of the resource base is increasing, and particularly in grains, sugar, cotton and dairy. Some of the off-site impacts of current production systems are being seriously researched, particularly the effects of wind and water erosion (grains and sugar), and of pesticide and phosphate contamination of water resources (cotton and dairy). Nevertheless, there is little work carried out, other than through the brokerage of the Land and Water Resources RDC and the New South Wales EPA, of integrated systems management where several industries contribute to off-site impacts within a region or catchment

What does agroforestry really mean for Australian farming systems? In the first national agroforestry conference held in 1991 the organisers and contributors demonstrated that a wide range of production systems are included, with many perennial and annual plant combinations that can be fitted into the specific requirements of combining income generation and resource management (36). Direct product harvesting may include native floriculture, nuts and fruits, as well as timber products. Indirect product harvesting includes systems of animal production that use saltbush, tagasaste and other woody perennials as well as conventional pastures, while using perennial tree and shrubs to improve production efficiency from existing systems includes windbreaks, utilisation of discharge water and perched groundwaters. The advent of the Forestry and Forest Products RDC, and the links formed between this corporation and the RIRDC and LWRRDC directed at improving reliable agroforestry options is welcome. The real challenge however, is that realistically, most of the tree production for wood products will take place in high to medium rainfall regions (over 700 mm), but the environmental impacts of extensive clearing for agriculture on regional hydrology, surface chemistry and erosion hazard are predominantly in the medium to low rainfall belts (600- 250 mm).

PREDICTIVE SYSTEMS RESEARCH

Agronomic research that seeks to minimise the off-site impact of farming on the environment asks different questions from the normal questions of productivity, because there is recognition of the impact of farming practices on food safety, water and air quality, ecological diversity and natural resource condition. The answers to sustainability questions need to be expressed in terms of maximum profit per hectare, minimum environmental cost and quality of product per input unit, rather than in yield per hectare. This brings us to the question of appropriate methodologies for investigating sustainability of current systems, and how to introduce whole new systems of land use and the plants that should be growing in them.

One of the intriguing challenges that new objectives and questions bring to old problems is that new methods develop to address these. In questions of sustainability the spatial scales being considered when the farm production area is reorganised to produce more from less shift the focus from experimental plot to landscape transects. As Squire and Gibson (37) have pointed out, there is a mismatch between the fine scale at which many scientists work and the lager scale at which land managers and policy makers require answers. The large time scales that are involved when soil properties are altered with any change in management system require a combination of episodic observation and modelling predictions based on a knowledge of functional relationships. The agronomist must then use the methodologies of the ecologist where the object of study more closely resembles the complexity and time-span of natural ecosystems rather than the highly simplified and regulated microcosm known as the randomised block experiment.

Most agronomists have had experience in being part of a team of scientists that includes skills in biometrics, pathology, micro-meteorology, soil science and plant breeding,- with the objective of improving a current production system, or introducing a new crop into a rotation or region. In a recent paper analysing the relatively low success rate of production research in southern Australia to improve cereal yields at district level French (38) makes a cogent plea for an integrated, system-scale approach to plant productivity research. Even when the research is of the single factor type, the agronomist is often the leader or synthesiser to the group, coordinating the design, methodologies and results of the component studies, and is therefore in a powerful position to introduce new approaches. If my view of the agronomist as leader and integrator is correct, future Australian agronomy conferences will be held jointly with the professional meetings of ecology, plant and soil science and ecological economics to consider novel land-use and product options at landscape scales.

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